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Title : LIGHT PULSE GENERATING APPARATUS AND COSMETIC AND THERAPEUTIC PHOTOTREATMENT

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Application No.	Country of Origin	Filed	Application No.	Country of Origin	Filed
97/0703	DENMARK	16 Jun 1997	9724775.3	GREAT BRITAIN	24 Nov 1997

Respectfully submitted,

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This is to certify the correctness of the following information:

The attached photocopy is a true copy of the following document:

- The specification, claims, drawings and abstract as filed with the application on the filing date indicated above

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An apparatus for generating a beam of light for selective phototreatment, an applicator for applying photoradiation, and a method for treating tissue with photoradiation.

REG. NR.: 207 235

The present invention relates to an apparatus for generating a beam of light for selective phototreatment.

The invention further relates to an applicator for applying photoradiation onto a tissue and in particular onto a live tissue such as human skin.

In a further aspect the invention relates to a method for treating live tissue for cosmetic purposes, including e.g. wrinkle smoothing, removal of hair or removal of tattoos or other undesired skin disorders.

In still another aspect the invention relates to a method of treating live tissue for therapeutic purposes including treatment for psoriasis, vascular traumas, telangiectasis, capillary hemangiom, cancerous cells, portwine stains, birthmarks, etc.

The publication WO 091/15264 describes a device for treatment of undesired skin disfigurements, which apparatus comprises a gas filled lamp and an optical filter. The lamp is powered by a capacitor charged to about 2,000 volts, which is sufficient for generating a pulse with a pulse duration between ½ and 1 ms.

The publication EP 0 565 331 A2 describes a therapeutic treatment device which includes a gas filled flash lamp and a set of optical filters. The power circuit includes three different pulse forming networks, which may be triggered selectively or successively. Each pulse forming network includes a capacitance and an inductance and a relay contact to trigger the discharge. The three networks are designed for providing different pulse widths. The capacitors are charged to a voltage, typically in the range of from 500 volts to 5 kilovolts.

The publication EP 0 736 308 A2 discloses a method and an apparatus for depilation, wherein an apparatus of a similar kind is used. According to this publication an energy fluence in the order of from 10 to 100 joules is used for the purpose of killing hair follicles without burning the surrounding skin. The publication also suggests the use of an optically transparent water-based gel applied to the skin prior to treatment and serving the purpose of providing a heat sink to prevent hyperthermia in the skin.

The inventors have found several limitations and problems in devices and methods according to the prior art. Damage to the skin or burns occur very easily, making it difficult to find an energy level at which the pulses will be effective but will not harm the skin. Cooling of the skin by means of gel to be applied to the skin requires a tedious and not very pleasant procedure. Further the amount of heat absorbed in the optical filters may be excessive, frequently leading to destruction of the filters.

These problems have been solved by the apparatus as recited in claim 1.

In this apparatus the power supply feeding the gas filled discharge lamp is adapted to keep the amplitude of the photoradiation generated to stay below a preselected maximum value and above a preselected minimum value. This method is distinguished over the prior art where the power supply typically comprises a capacitor which is discharged to feed current through a series inductance and into the arc lamp. The prior art circuit creates a current pulse shaped approximately as one half period of a sine wave, rising from zero to a maximum and declining

again to zero. The invention aims at driving the arc lamp on a current pulse shaped approximately as a square wave.

Arc lamps may be driven at different current levels, outputting different levels of optical radiation, however, with an associated shift in the spectrum. Thus the variation of the radiation in the short wave length range, e.g. below 700 nm tends to vary more than the variation in the longer wave length range. For instance on recording the optical output spectral density generated while driving an arc lamp at 100% and at 50% of maximum rated current, it was found that the optical output spectral density at 900 nm dropped to 67% of the preceding value, whereas the output at about 480 nm dropped to about 40% of the respective preceding value.

For depilation, optical radiation at wave lengths longer than 700 nm is favored for its ability to penetrate deeper into the skin. Thus, for this application the short wave length radiation is regarded as an unwanted output to be filtered away in optical filters. The result is an excessive power dissipation in the filters.

The changing spectrum of the arc lamp if driven on a varying current as provided by power supply units according to the prior art, also makes it very difficult to estimate the effective output after the filters. According to the invention the lamp is driven on a substantially constant level of current, where the spectrum then is approximately unchanged and the energy delivered to the target proportionate to the duration of the square wave pulse.

The generation of this kind of drive signal requires a different electric circuit, which operates with a higher intrinsic power loss compared to the circuits of the

prior art. The invention therefore achieves the result referred to only at the cost of an increased power loss in the electric driving circuit. The shifting of the power loss to take place in the power supply unit rather in the optical filters is considered a major advantage, since power dissipated in the power supply unit may easily be kept away from the patient and from the sensitive optical components in the applicator.

The capability of the apparatus according to the invention of reducing the amplitude of the power output may be used to a substantial advantage. The inventors have found that the skin epidermis is capable of absorbing a greater amount of energy input than the tissue in the hair follicle. The difference, which may be in the order of factor of 20, is attributed to the greater thermal conductivity in the epidermal region. This difference more than offsets the disadvantage of the more limited penetration to the hair follicles.

Hence, for a given irradiation input, the hair follicle is heated to a higher temperature than the epidermis. This means that it is possible to establish a level where the hair follicles may be killed without harming the epidermis. The exact level may vary depending on skin pigmentation and has to be established for the particular patient. The procedure of establishing a proper level is considered to lie within the capabilities of those skilled in the art. The apparatus according to the invention is capable of outputting a treatment signal at a power level which is accurately controlled, in order to provide just the desired irradiation input.

The invention further provides an applicator as recited in claim 7.

In this applicator a photodetector detects light reflected from the tissue. This measurement result provided by the photodetector gives an indication of the skin pigmentation of the person being treated. The measurement result obtained from the photodetector may be utilized to provide information about the patient and to control and verify the operation of the system.

The invention further provides a method of treating live tissue for cosmetic purposes as recited in claim 10. Cosmetic treatments envisaged comprise hair depilation, tattoo removal, wrinkle smoothing, skin rejuvenation, removal of disfiguring skin ailments and birthmarks, etc.

The invention further provides a method for treating live tissue for therapeutic purposes as recited in claim 11. Therapeutic purposes envisaged comprise treatment for psoriasis, vascular traumas, telangiectasis, capillary hemangions, cancerous cells, removal of birthmarks, etc.

Preferred embodiments of the invention are recited in the claims.

Further objects, features and advantages of the invention will appear from the appended detailed description given with reference to the enclosed drawings, wherein

Figure 1 illustrates a circuit diagram of the power supply with the lamp,

Figure 2 illustrates a transverse cross-section through the applicator,

Figure 3 illustrates a longitudinal cross-section through the applicator of Fig. 2,

Figure 4 is a time chart of the current fed through the lamp during a pulse, and

Figure 5 is a chart of the luminous spectral density of the output of a Xenon lamp.

All drawings are schematic, illustrating only features essential to enable those skilled in the art to practice the invention whereas other features are omitted from the drawings for the sake of clarity. Throughout the drawings the same references are used to designate identical or similar features.

Reference is first made to Fig. 1 illustrating the driving circuit and the lamp.

The circuit in Fig. 1 comprises a control unit in the form of a personal computer PC used to control the system. The PC is connected to a power supply which is adapted to charge through the diode D1 the capacitor C. In a preferred embodiment the power supply is adapted to charge the capacitor to a voltage set from the PC to a level in the range from 100 - 1000 volts. In a preferred embodiment the capacitance of the capacitor C is 100 mF.

The capacitor C is connected through diode D2 and resistor R to the flash lamp FL. The circuit is completed by a solid state switch IGBT, which is in the preferred embodiment implemented in the form of an isolated gated bi-polar transistor. The IGBT is controlled from the PC by the line designated SHOOT. The IGBT is capable of changing from non-conductive to conductive state, of carrying currents in the range of 500 A and of changing from conductive to non-conductive state again, breaking this current.

On the right hand side of Fig. 1 a simmer power supply is illustrated. This power supply is capable of feeding the flash lamp through the diode D3 with a simmer current in the order of 100 mA. In order to ignite the flash lamp the simmer power supply outputs a short pulse at a voltage of about 10 - 20 kilovolts on the electrode designated TRIGGER. The simmer current maintains a narrow arc inside the gas-filled lamp to keep this lamp in the conductive state.

Fig. 1 also illustrates photodetector 9 adjacent the flash lamp and connected to convey data about the illumination level to the control unit PC.

Reference is now made to Fig. 2 illustrating a vertical transverse section in the applicator according to the invention. The applicator comprises housing 1, lamp 3, reflector 2 surrounding the lamp, IR filter 5, removable filter 6, light guide 7 and pressure relief device 8. The reflector 2 is shaped to direct the light output of the lamp downwards as illustrated in the figure. The edge of the reflector 2 constitutes the aperture 10.

The reflector together with the IR filter forms a generally closed chamber 4 which is filled with water.

The pressure relief device comprises a bulb-like expanded chamber filled with air and in fluid communication with the chamber 4. This air-filled chamber acts like a spring capable of smoothing out any pressure shocks in the water chamber that may be caused by the sudden discharges of the lamp.

The IR filter 5 is adapted to absorb a part of the light in the infrared range.

The removable filter 6 may be substituted with other filters of similar type in order that the operator may chose from a selection of filters with different optical band widths.

Reference is now made to Fig. 3, which illustrates a vertical longitudinal section through the applicator from Fig. 2. Fig. 3 illustrates generally the same parts as those appearing in Fig. 2 plus the photodetector 9 in the upper portion and the water conduits 11 carrying water for cooling the interior of the applicator. The photodetector detects light reflected from the skin, preferably at the low level of irradiation prevailing during intervals of simmer operation, enabling the system to estimate the reflectivity or the pigmentation of the skin. The photodetector further enables the system to verify the proper operation of the flashing circuitry.

Fig. 3 symbolically illustrates an area of treatment comprising epidermis 12, dermis 13 and a hair 14 in a hair follicle 15.

Reference is now made to Fig. 4 illustrating a time chart of the current fed through the Xenon lamp during a pulse of treatments. Fig. 4 illustrates a pulse of a duration of 100 ms. The pulse rises practically immediately to a level of 338 A and decays exponentially to about 276 A after 100 ms.

Thus, the circuit of the preferred embodiment approximates the desired square wave by a sloping exponential decay with a time constant depending on the capacitance of the capacitor and the current driven through the Xenon lamp. Generally, satisfactory results are achieved if the current decays from 100% to somewhere above 50% of the initial value.

Reference is now made to Fig. 5 illustrating a chart of power spectral density of the radiation output by the Xenon lamp. Fig. 5 comprises two graphs, one drawn for a Xenon lamp at a current density of 2400 A per cm^2 and illustrating the optical output from a wave length about 420 nm up to about 1100 nm, the other curve showing the output of a current at half of this level. The curve illustrates the fact that the spectral output drops disproportionately on the reduction of the drive current. For instance at 900 nm the output drops to approximately 65% while the output at 480 nm drops to about 40%, both taken relative to the respective preceding values.

In order to use the system for treatment, an operator would place the applicator adjacent a selected treatment area and set the control unit to carry out an initialization routine. As part of this routine, the operator would enter data into the control unit concerning the patient and the type of treatment desired. In one preferred embodiment, the control unit is programmed to ignite the flash lamp and burn it on the simmer power supply in order provide a low level of irradiation, by which the control unit through the utilization of the photodetector will establish the reflectivity value of the treatment area. These data enable the control unit to suggest an appropriate irradiation scheme, which may comprise pulse level and pulse duration.

Once the operator has accepted the treatment scheme, he will the only need to move the applicator to the respective treatment areas and activate a trigger, while the control unit will verify that contact is established, and that the reflectivity has the presumed value, and will then output the appropriate treatment signal.

Although various components, systems and methods have been explained in particular settings above, this is not to exclude that such components, systems or methods might be applied in other settings or applied differently. The particular examples mentioned have only been mentioned with the purpose of facilitating the understanding of the invention and not with the purpose of limiting the scope whereof which is defined exclusively by the appended patent claims.

PATENT CLAIMS

1. An apparatus for generating a beam of light for selective phototreatment comprising:
- a light source operable to provide an output of incoherent photoradiation for treatment,
- a power supply connected to the light source,
- a housing including a reflector and an aperture,
- an optical filter adapted for passing only a selected band of optical wavelengths, c h a r a c t e r i z e d in that:
- the power supply is adapted to feed the light source for a predetermined interval of time and in such way as to keep over this predetermined interval of time the amplitude of the photoradiation output to stay below a preselected maximum value and above a preselected minimum value.

2. The apparatus according to claim 1, c h a r a c t e r i z e d in that the preselected minimum value is at least 50% of the preselected maximum value.

3. The apparatus according to claim 1 or 2, c h a r a c t e r i z e d in that the power supply is provided with means for adjusting the level of the preselected maximum value according to the treatment required.

4. The apparatus according to any of the preceding claims, c h a r a c t e r i z e d in that the light source comprises a gas-filled arc lamp such as a Xenon or a Krypton lamp.

5. The apparatus according to any of the preceding claims, c h a r a c t e r i z e d in that the power supply comprises a capacitor battery, a charging circiut adapted for charging the capacitor battery to a preselected voltage, a series resistor and a discharge switch operable to change from non-conductive state to conductive state and back to non-conductive state again.

6. The apparatus according to claim 5, characterized in that the power supply comprises a simmer generator adapted for feeding the lamp with power at a level which is sufficient to keep the arc in the conductive state.

7. An applicator for applying photoradiation onto a tissue, comprising:
- a housing including a reflector and an aperture,
- a gas-filled arc-lamp,
- an optical filter adapted for passing only a selected band of optical wavelengths,
- a light guide for transmitting light from the aperture to the tissue, and
- a photodetector adapted for detecting light reflected from the tissue.

8. The applicator according to claim 7, c h a r a c t e r i z e d in that it comprises means for cooling by water.

9. The applicator according to claim 8, c h a r a c t e r i z e d in that it comprises a pressure relief device.

10. A method of treating live tissue for cosmetic purposes, wherein an apparatus as defined in any of the claims 1 through 6 or an applicator as defined in any of the claims 7, 8 or 9 is used.

11. A method of treating live tissue for therapeutic purposes, wherein an apparatus as defined in any of the claims 1 through 6 or an applicator as defined in any of the claims 7, 8 or 9 is used.

ABSTRACT

An apparatus for generating a beam of light for selective phototreatment comprises a light source (3) operable to provide an output of incoherent photoradiation for treatment, a power supply connected to the light source, a housing (1) including a reflector (2) and an aperture (10), and an optical filter (5, 6) adapted for passing only a selected band of optical wavelengths. According to the invention, the power supply is adapted to feed the light source for a predetermined interval of time and in such way as to keep over this interval of time the amplitude of the photoradiation output to stay between predetermined limits.

The invention further provides an applicator for applying photoradiation onto a tissue, a method of treating live tissue for cosmetic purposes and a method of treating live tissue for therapeutic purposes.

Fig. 3 to be published with the abstract.

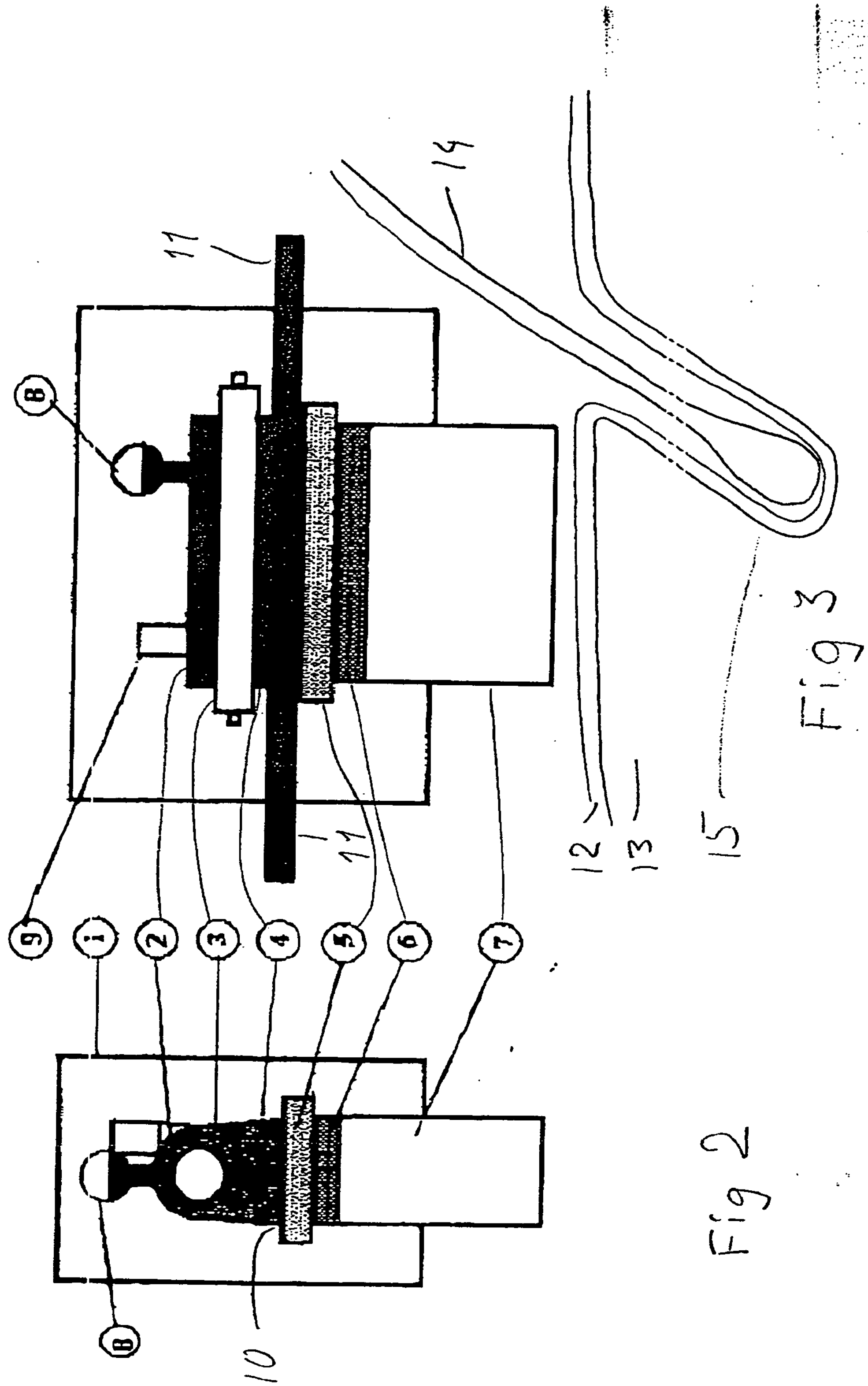

Fig 3

Fig 2

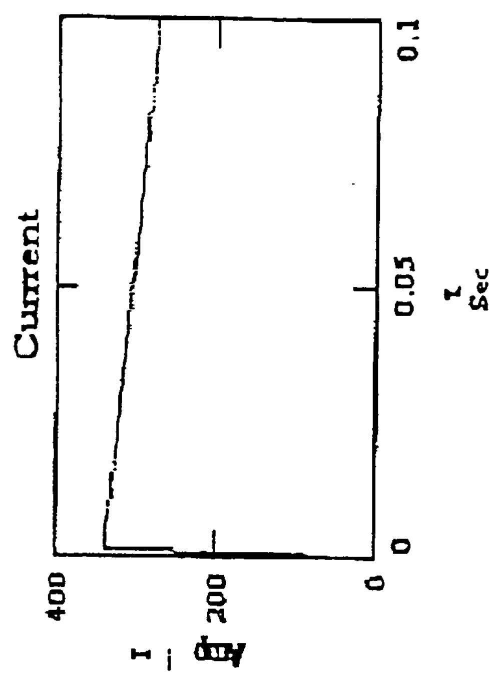

Fig 4

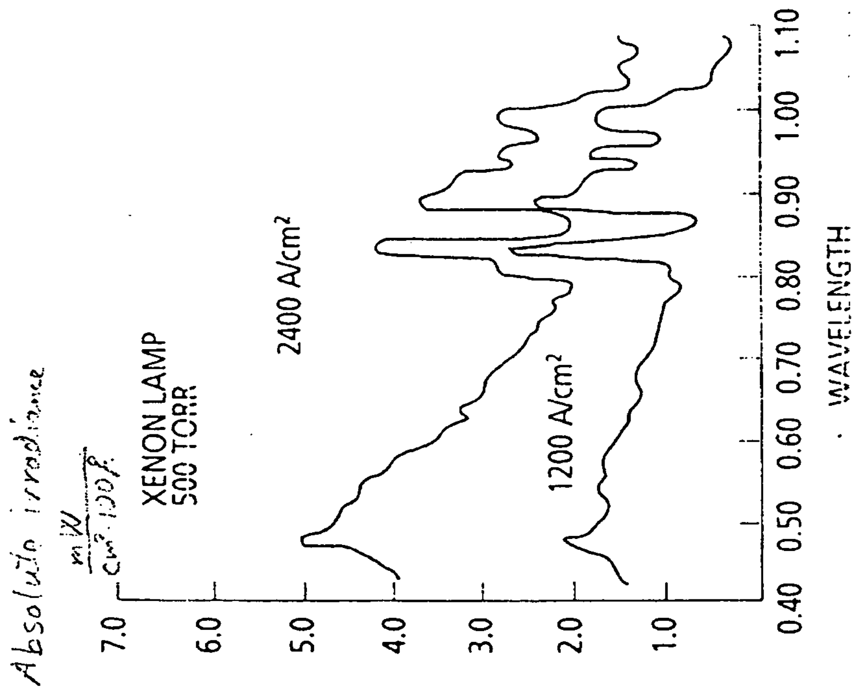
Absolute irradiance
mW / cm² 100 Å
XENON LAMP
500 TORR
2400 A/cm²
1200 A/cm²
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1.10
WAVELENGTH

Fig 5

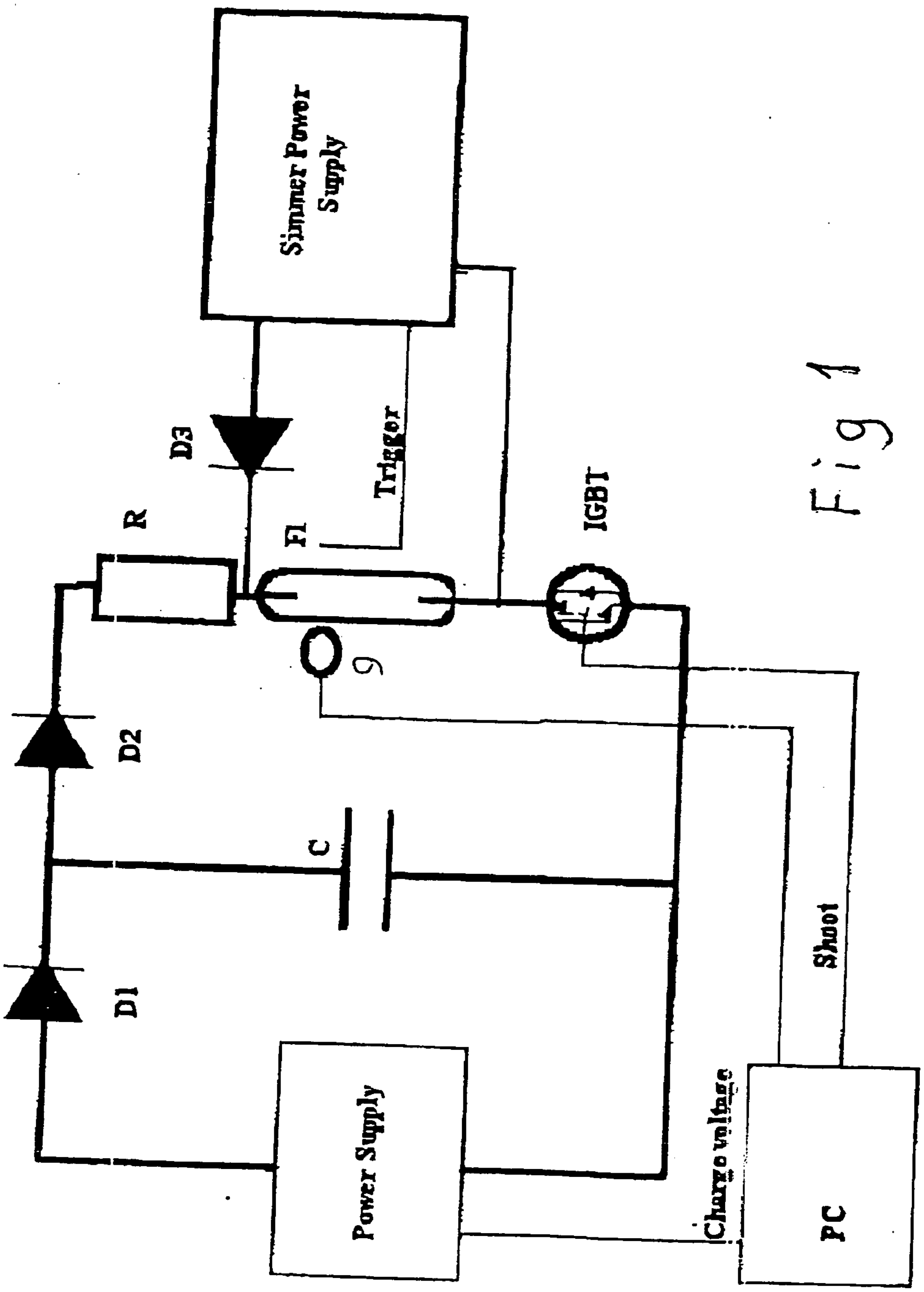
Simmer Power Supply
D3
Trigger
R
Fl
IGBT
9
D2
C
D1
Power Supply
Charge voltage
Shoot
PC

Fig 1